Development of an Extreme Environment DC Motor Drive Full Bridge Power Stage Using Commercial-Off-The-Shelf (COTS) Components

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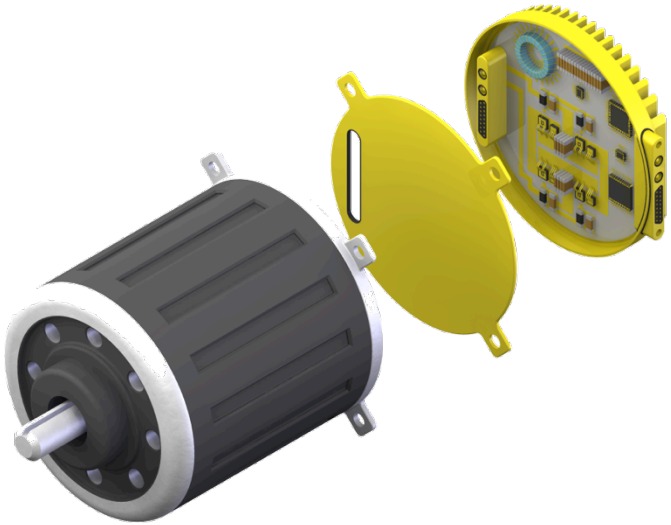
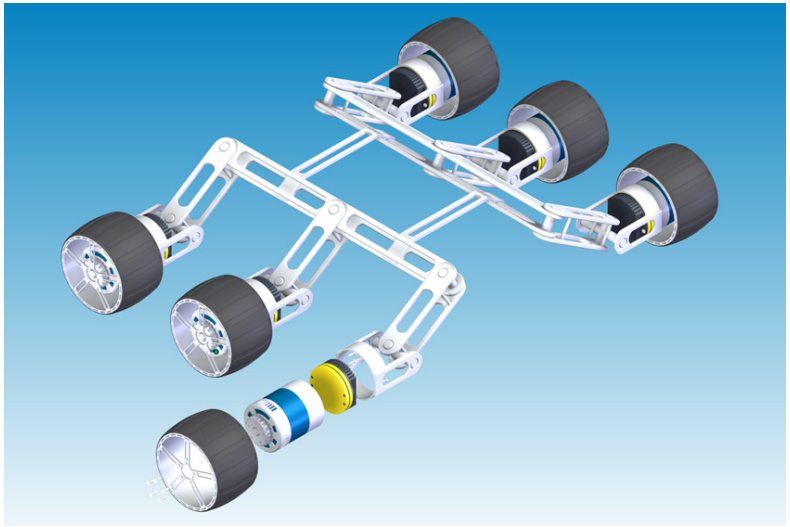
Introduction

- DC Motor drives are needed to properly control the DC motors aboard spacecraft.
- Spacecraft electronics encounter extreme environments, such as cryogenic temperatures down to -230 ºC
- Radioisotope Heating Units (RHUs) are used to keep the electronics warm (about 20 ºC)
- RHUs continually produce heat, are expensive, and add complexity and weight to the spacecraft
- Some commercial-off-the-shelf components (COTS) have been found to work reliably at cryogenic temperatures, thus avoiding the use of RHUs

Motor and Integrated Motor Drive



Possible Application



Outline

- Test Setup
- Passive Elements
  - Resistors
  - Capacitors
- Active Elements
  - High/Low Side Gate Drivers
  - Diodes and Transistors
- DC Motor Drive Full Bridge Power Stage
- Summary

* NASA images

Test Setup

Delta Design 9028 Environmental Test Chamber

- Uses liquid nitrogen
- Lowest temperature: -184 ºC
- Most components tested at:
  25 ºC, 0 ºC, -55 ºC, -100 ºC, -125 ºC, -175 ºC, -184 ºC

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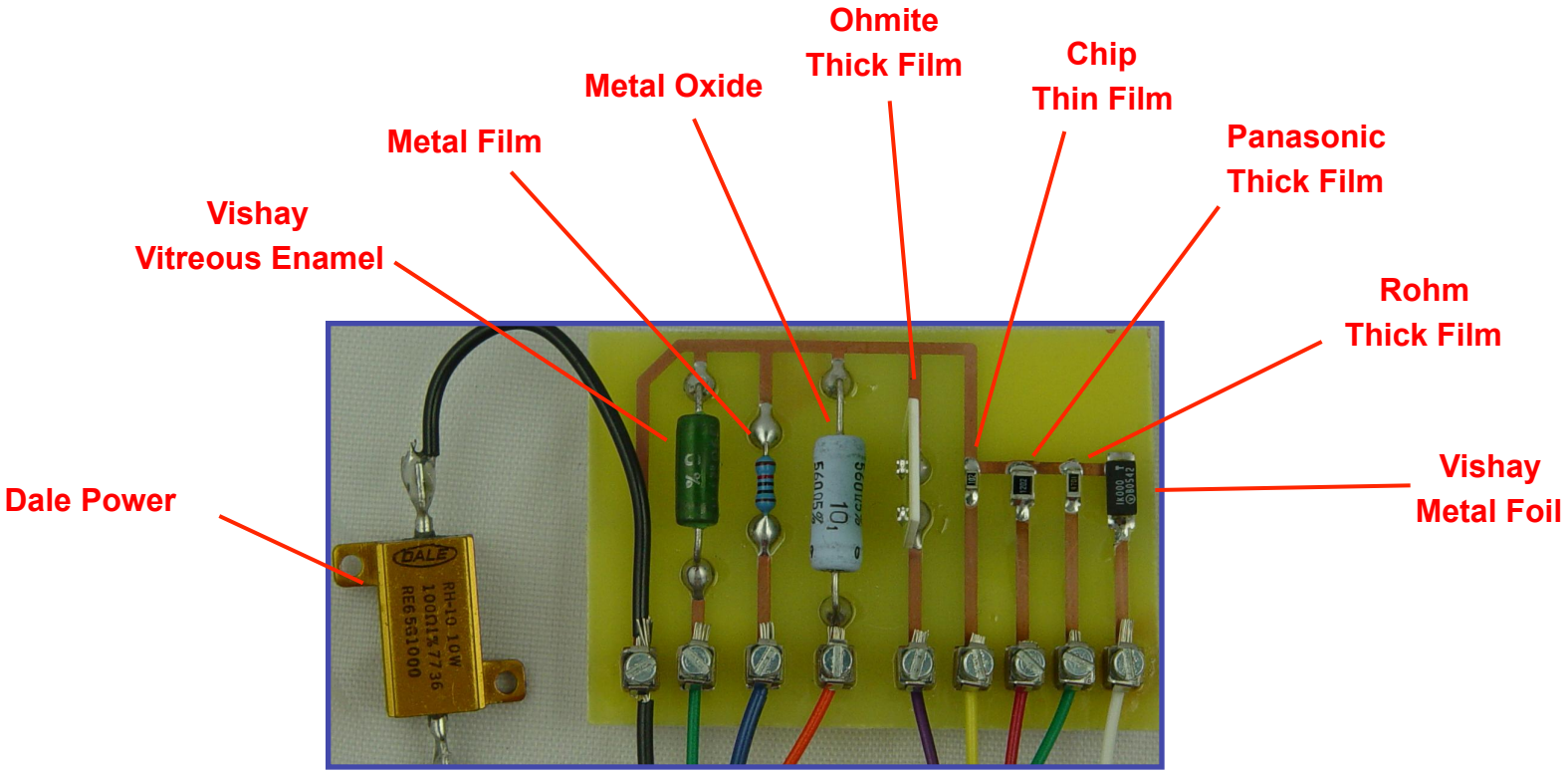
Passive Elements - Resistors



Measurements

- Resistance

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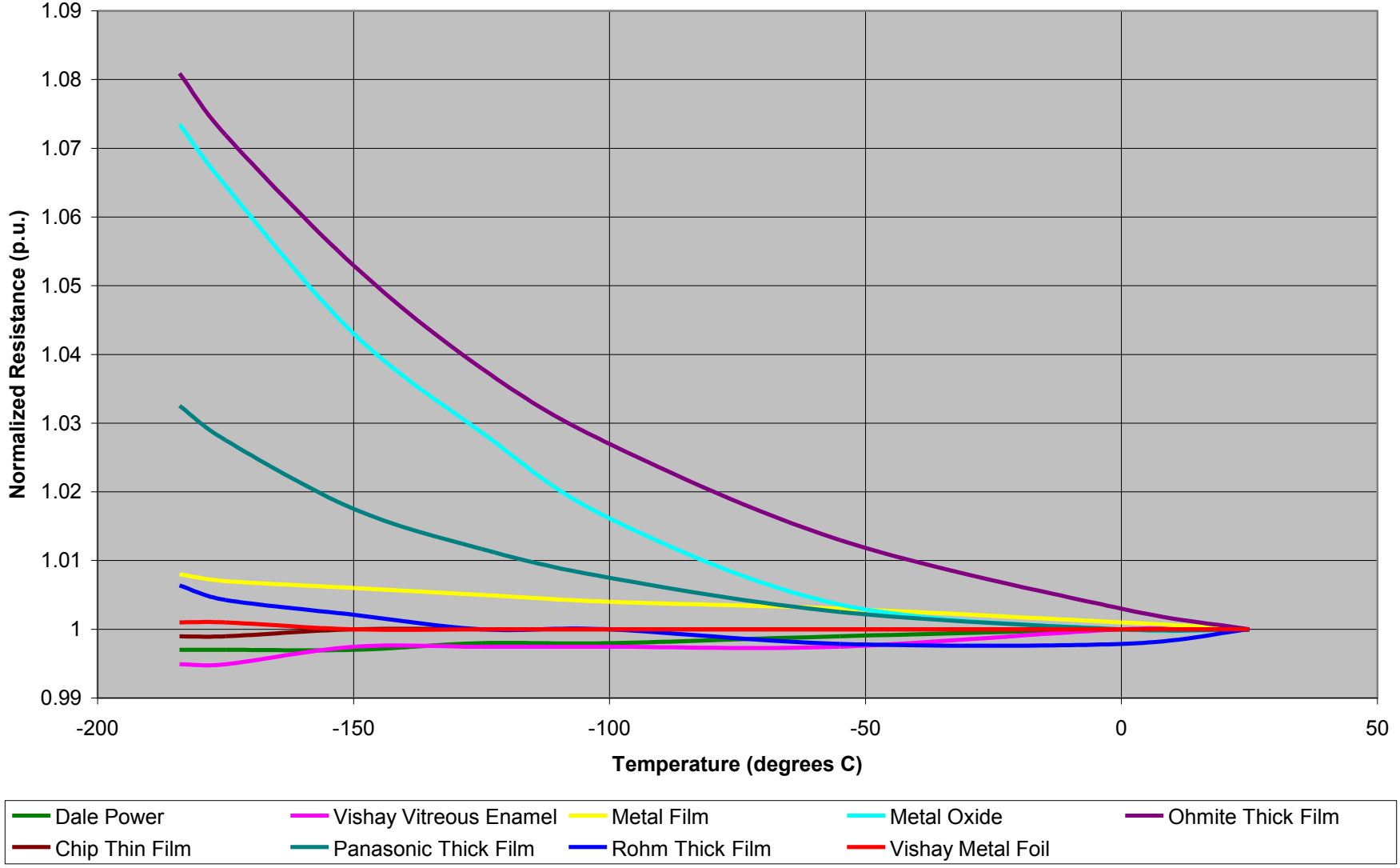
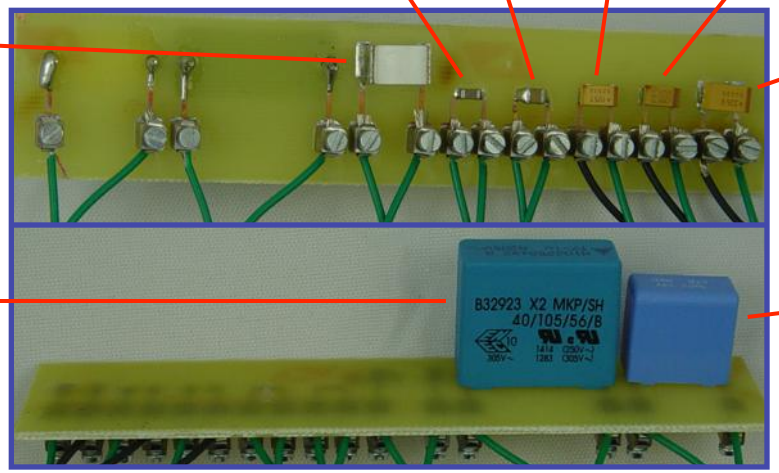
Resistor Test Results



Passive Elements - Capacitor



Measurements

- Capacitance (0V & 30 VDC Bias)
- Dissipation factor (0V & 30 VDC Bias)

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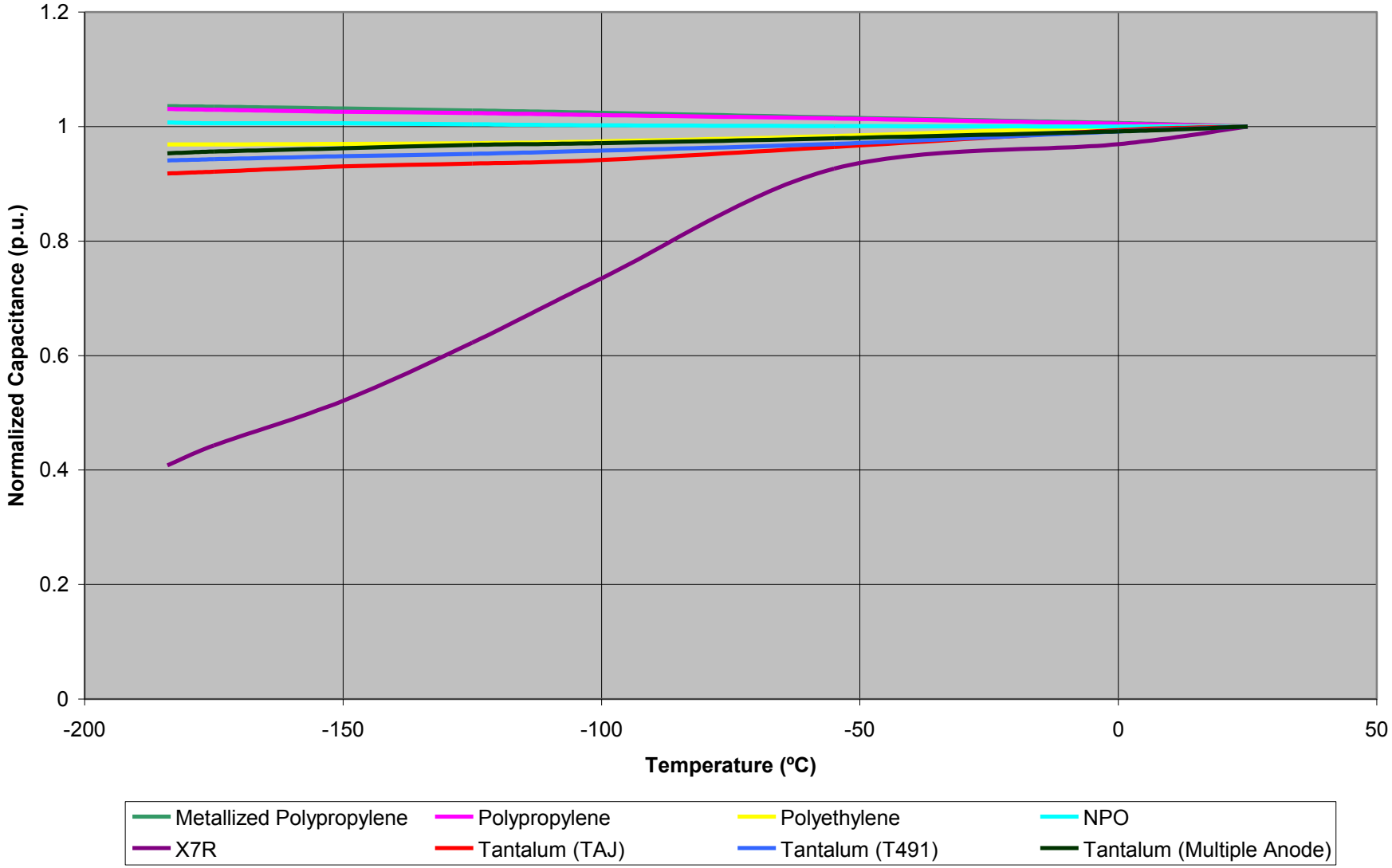
Capacitors (30 VDC Bias)



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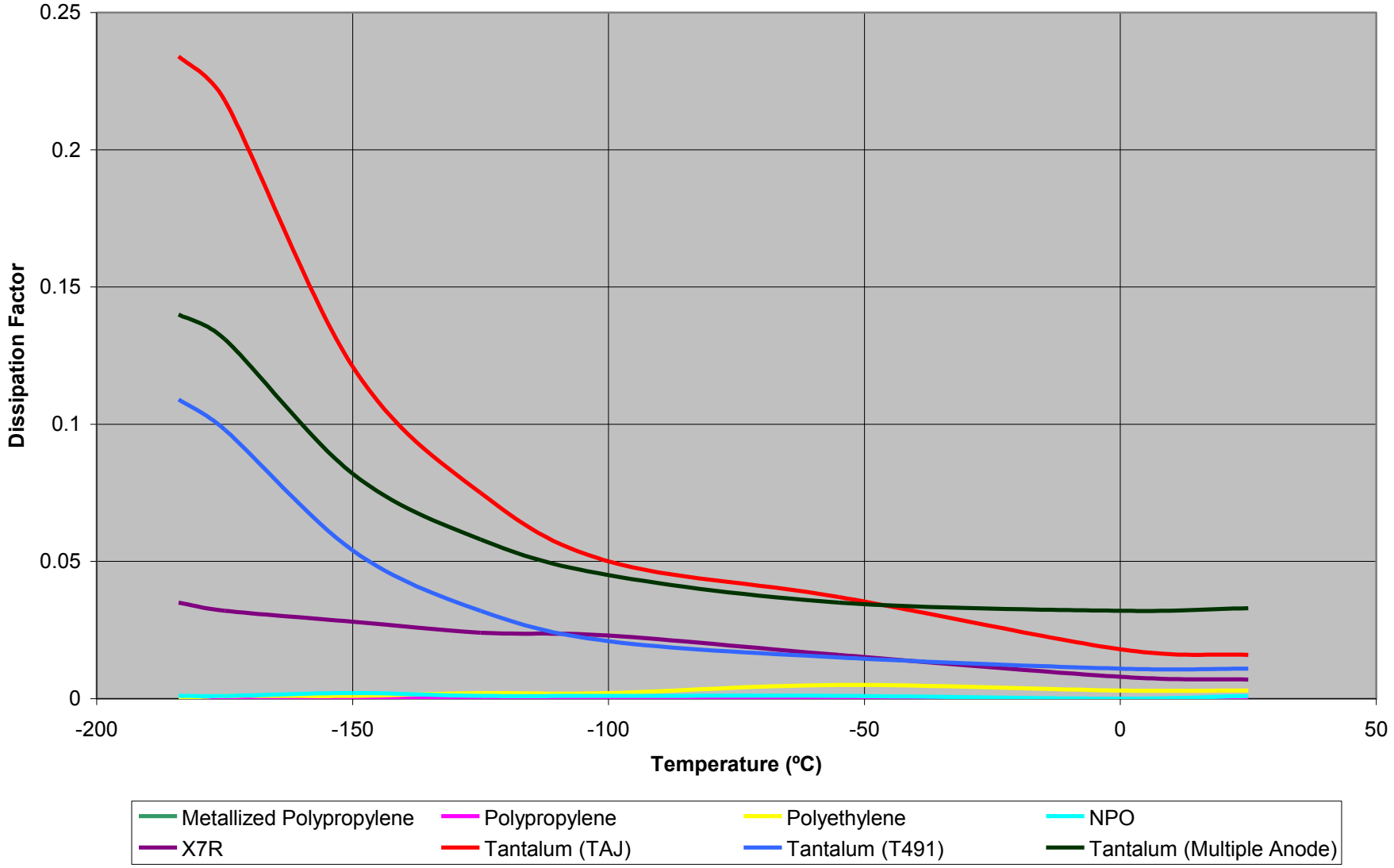
Dissipation Factor (30 VDC Bias)

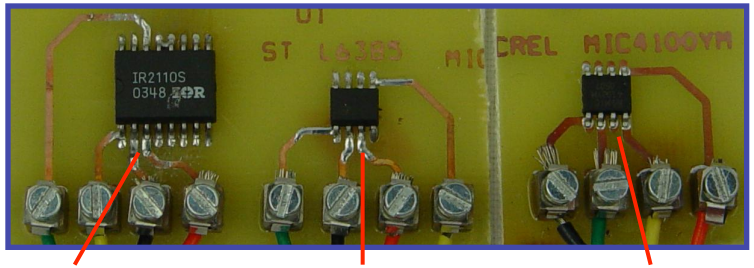


Active Elements - High/Low Side Gate Drivers

Process Technologies

- Silicon
- SOI (Silicon-On-Insulator)

Silicon Gate Drivers



International Rectifier IR2110

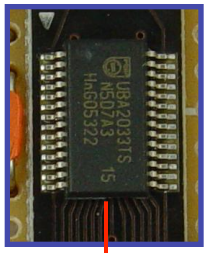
ST Microelectronics L6385

Micrel MIC4100YM

Measurements (Low Side Load - 1000pF)

- Turn-on rise time t_{rise}
- Turn-off fall time t_{fall}
- Turn-on propagation delay t_{on}
- Turn-off propagation delay t_{off}

SOI Gate Driver



Phillips UBA2033

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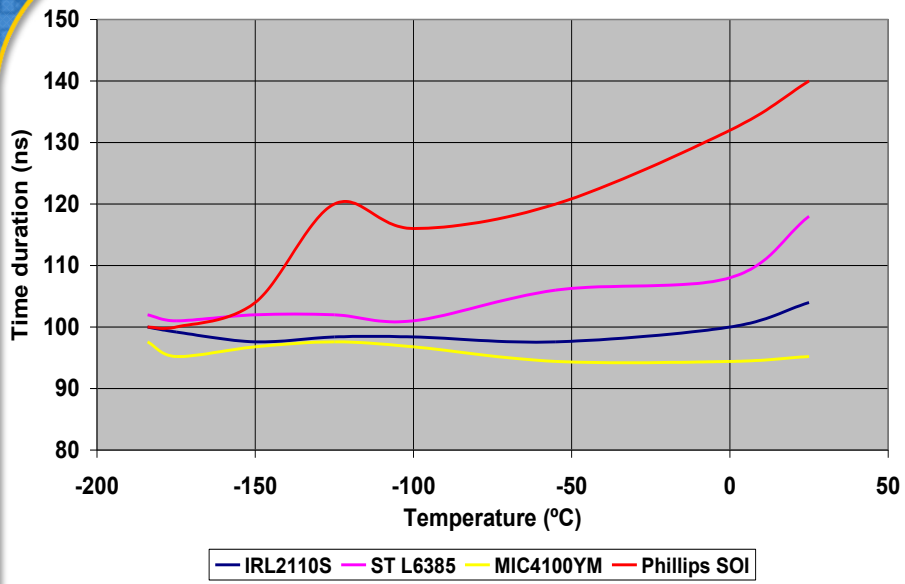
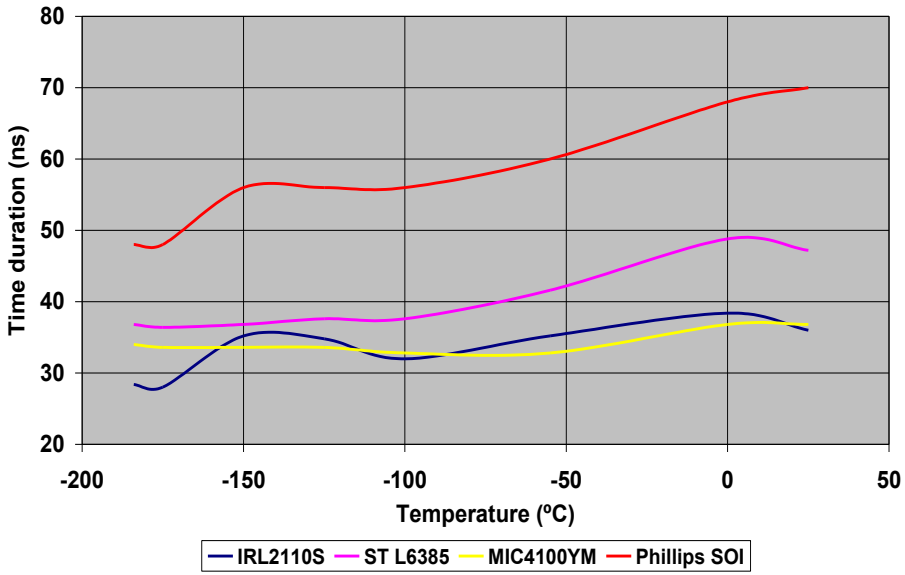
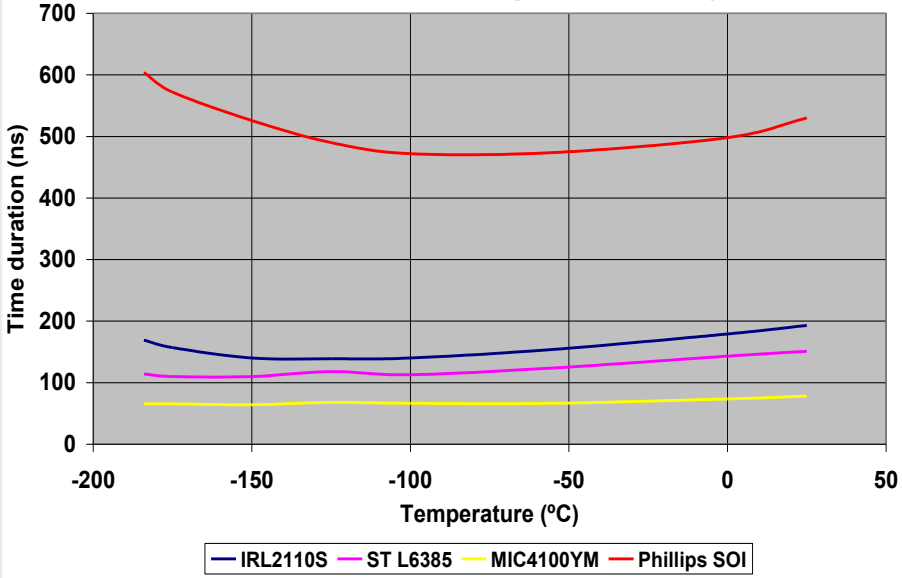
Turn-on Rise Time



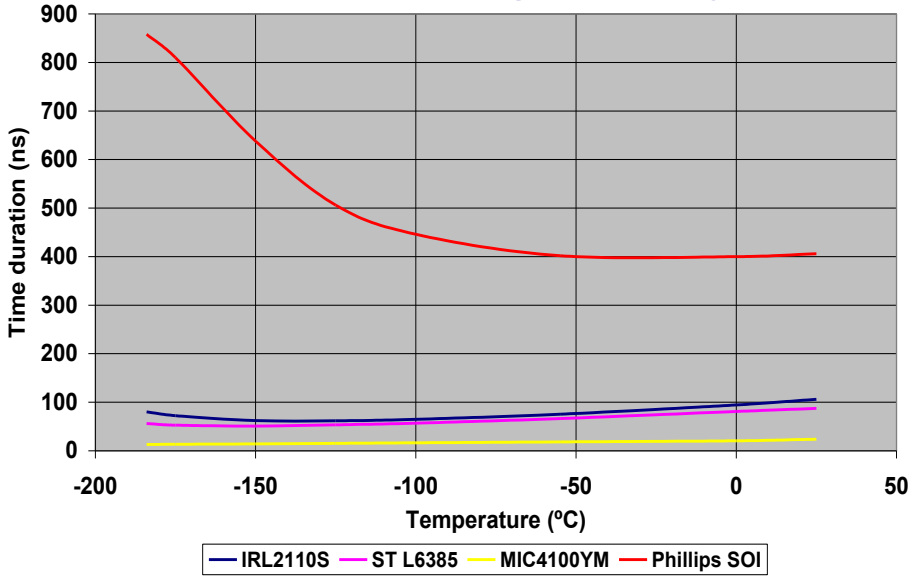
Turn-off Fall Time



Turn-on Propagation Delay



Turn-off Propagation Delay



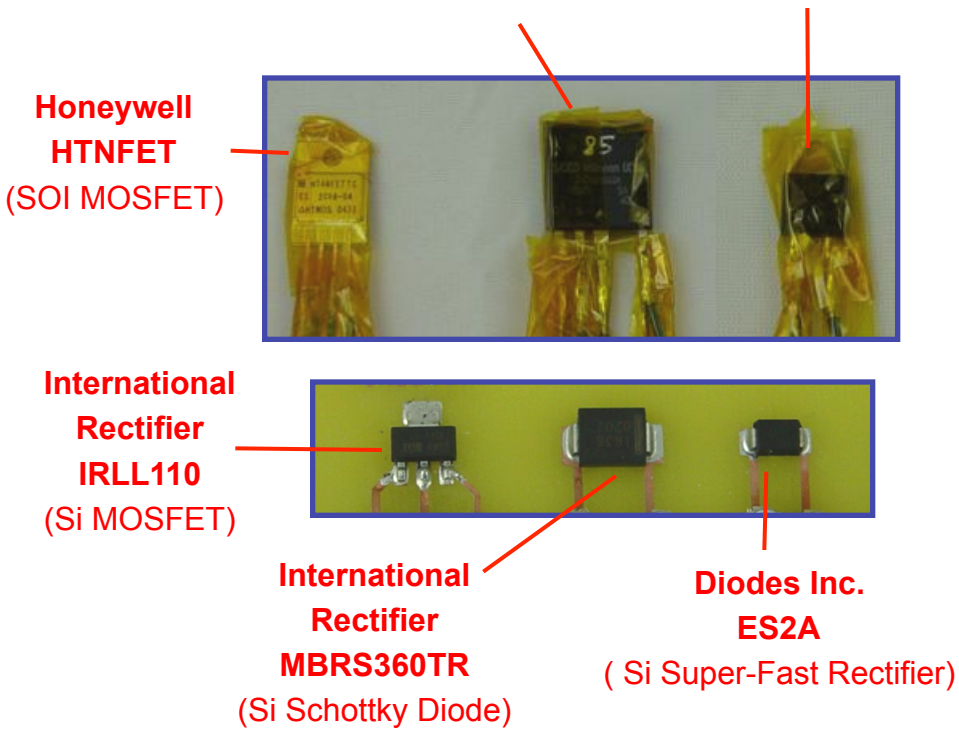
Diodes & Transistors

Diode Technologies

- Silicon Schottky
- Silicon super-fast
- SiC Schottky

Transistor Technologies

- Silicon MOSFET
- SOI MOSFET
  (Silicon-On-Insulator)
- SiC Cascode
  Silicon MOSFET cascoded with SiC JFET



Measurements

- Diodes
  - Forward voltage
  - On-resistance
  - Reverse breakdown voltage
- Transistors
  - Threshold voltage
  - On-resistance
  - Breakdown voltage

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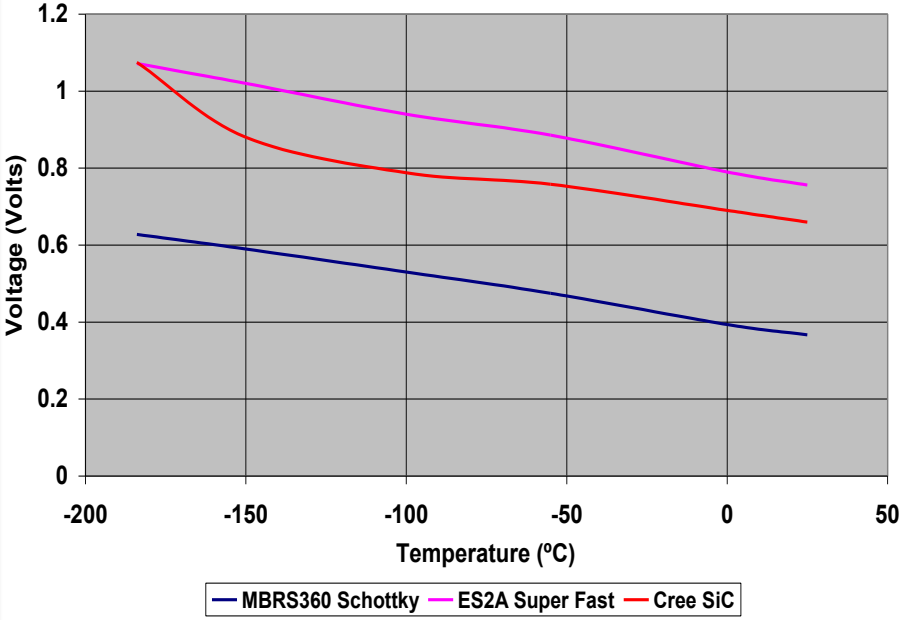
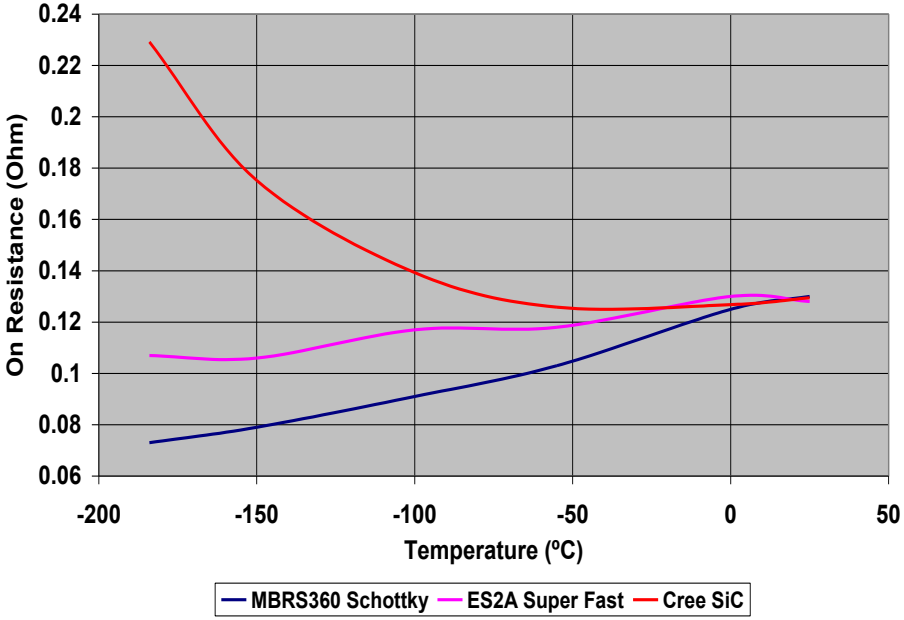
Diode Measurements

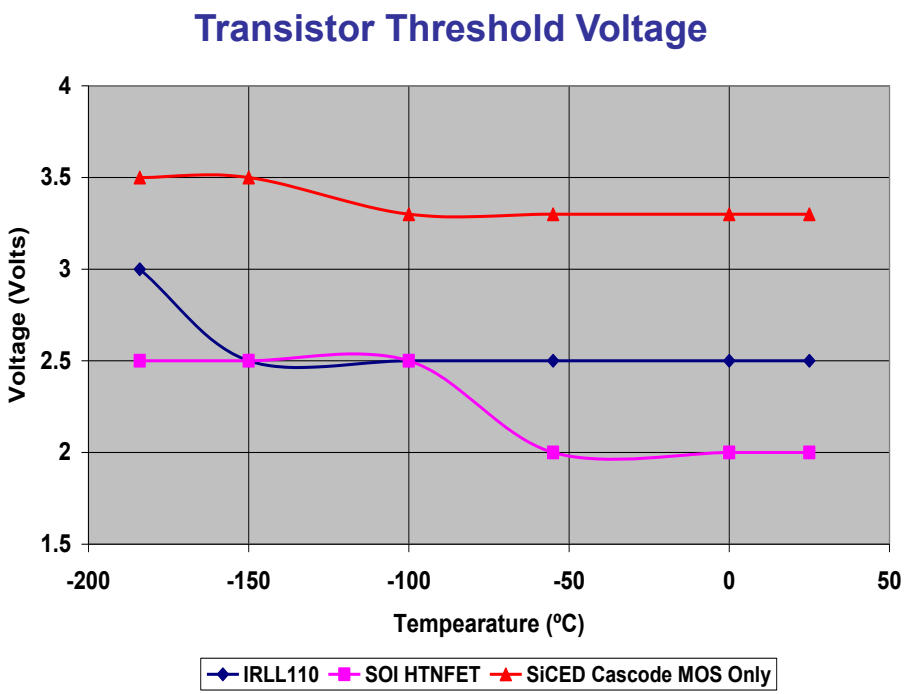
Diode Forward Voltage

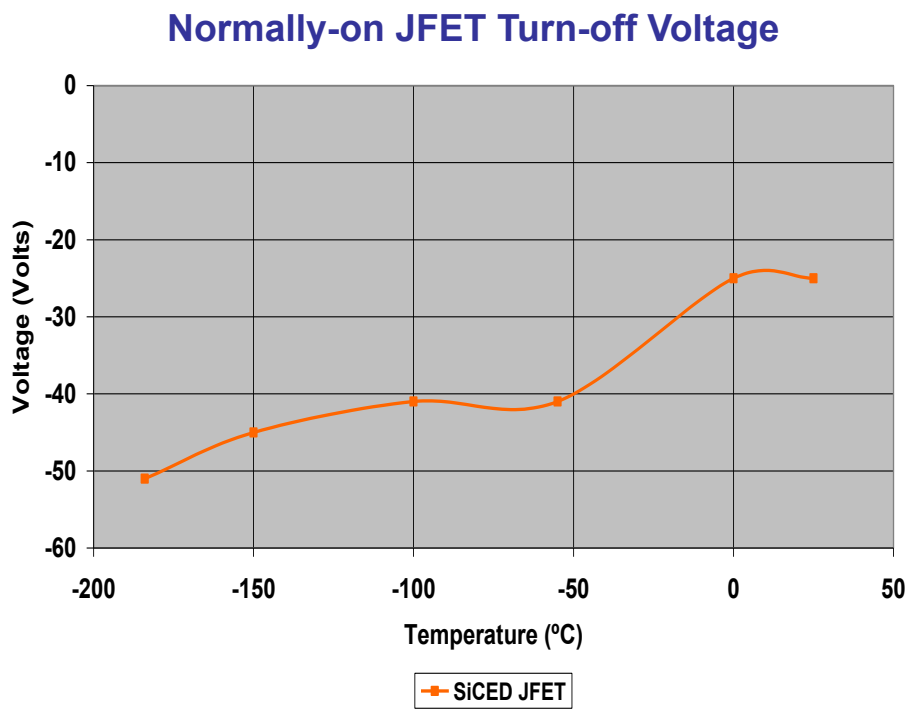


Diode On-Resistance



Transistor Measurements





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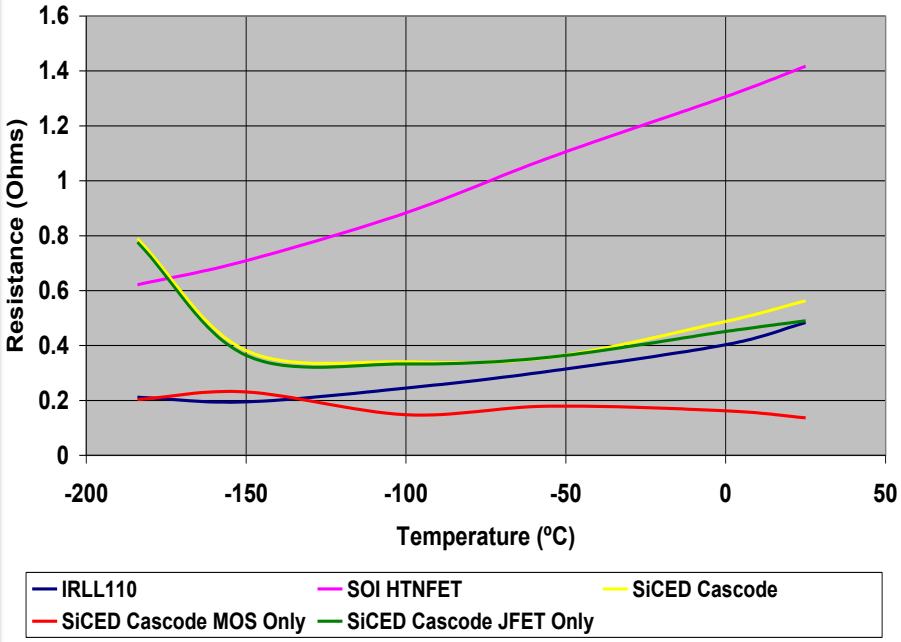
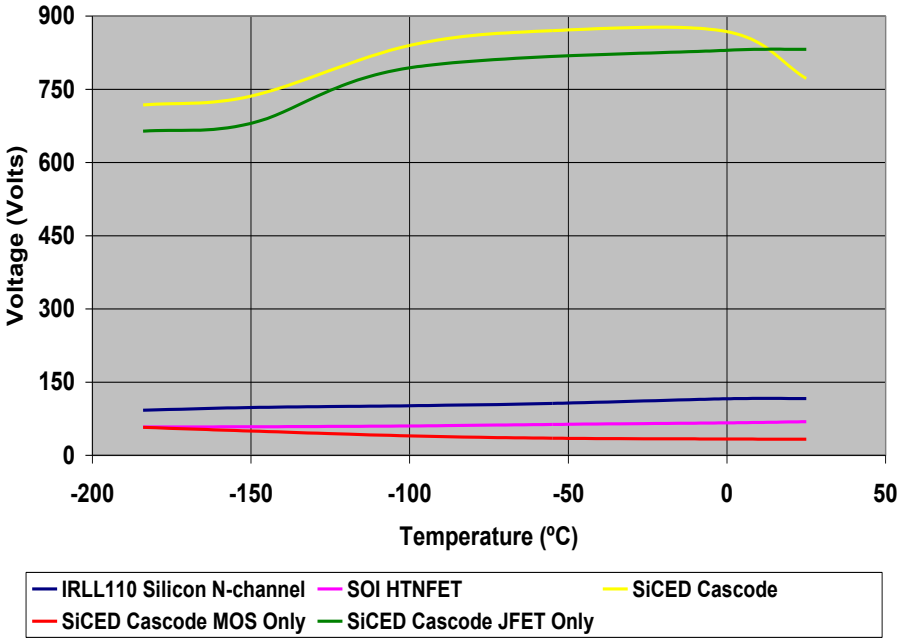
Transistor Measurements

Transistor On-Resistance



Transistor Breakdown Voltage



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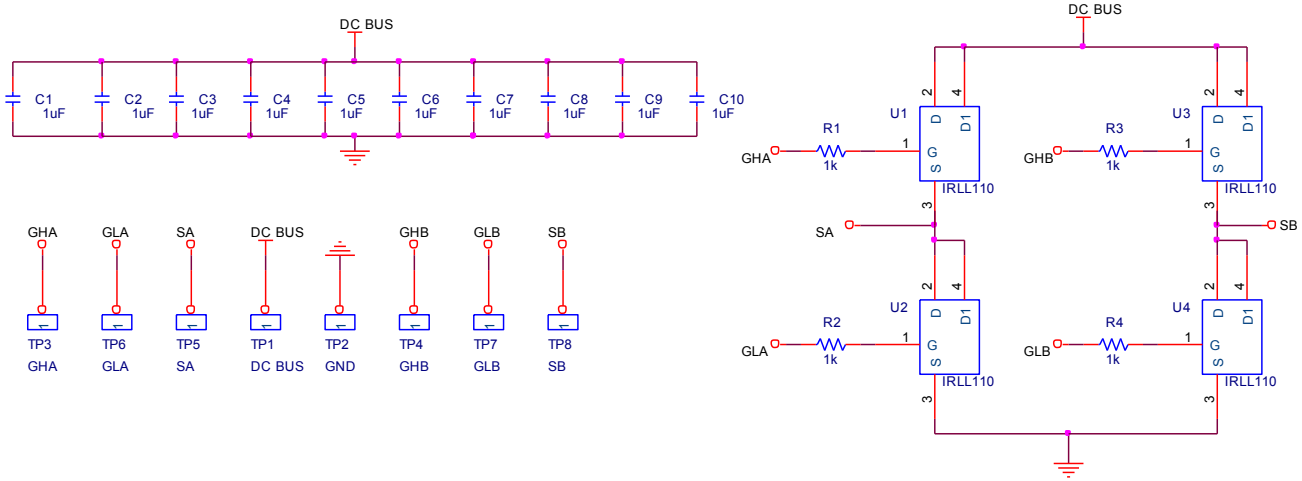
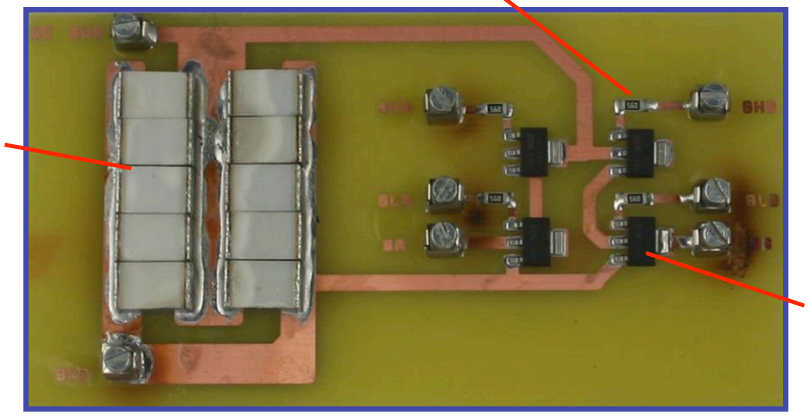
DC Motor Drive Full Bridge Power Stage

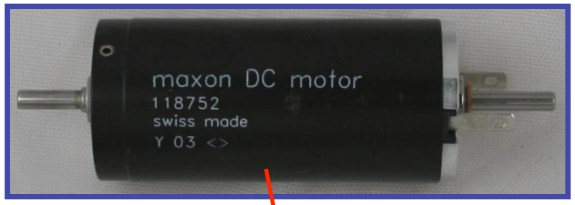


Rohm Thick Film Resistors

Polyethylene Capacitors



IR IRLL110 Transistors



Maxon RE 25
20 Watt DC Motor
(used on Mars rovers)

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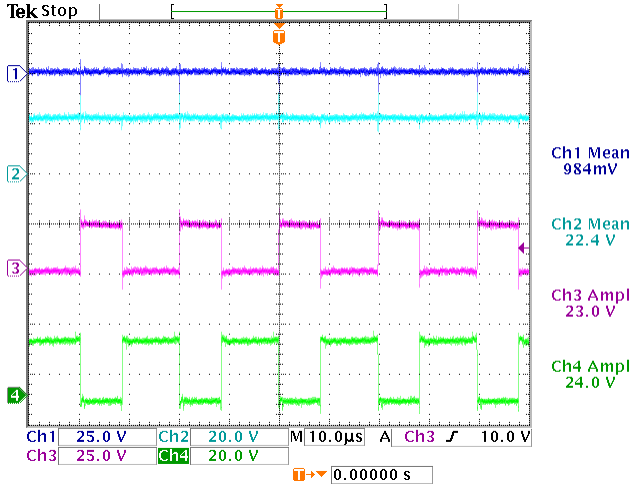
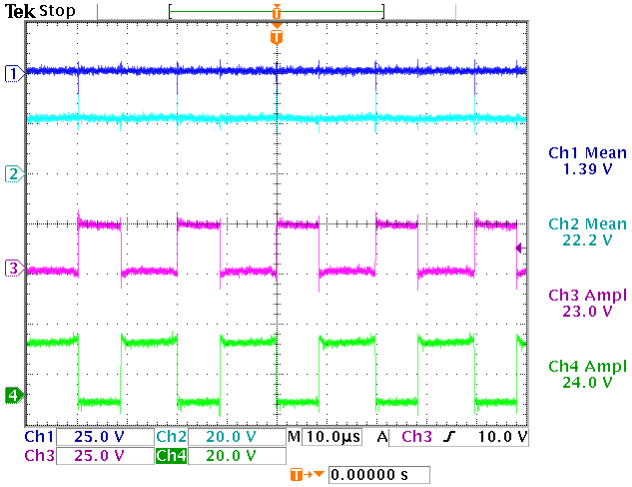
DC Motor Drive Full Bridge Power Stage

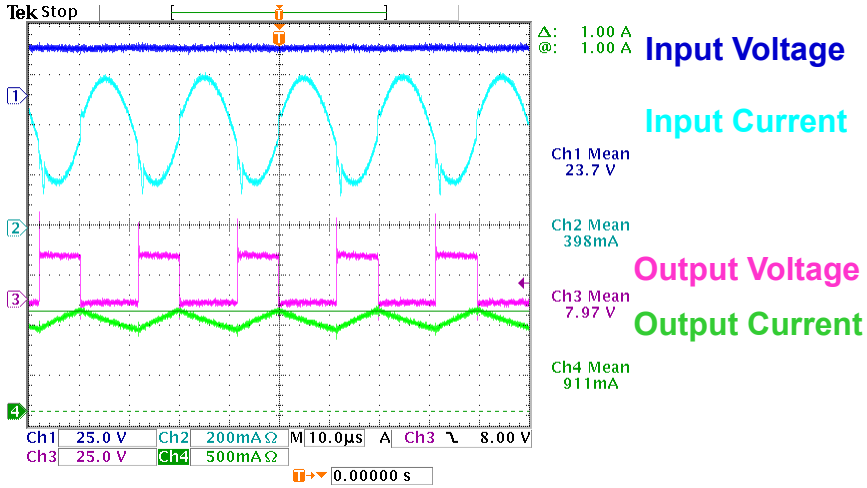
Drain-to-Source Voltages @ 25 ºC



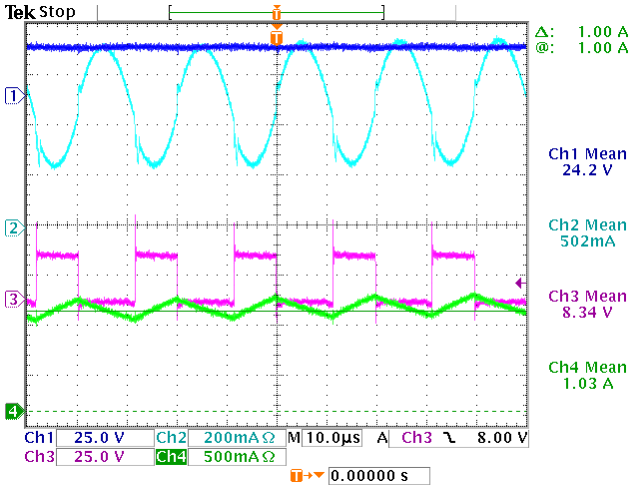
Drain-to-Source Voltages @ -184 ºC



Input/Output Voltages & Currents @ 25 ºC



Input/Output Voltages & Currents @ -184 ºC



Summary

- Cryogenic testing of COTS components
  - Resistors
  - Capacitors
  - High/Low Side Gate Drivers
  - Diodes
  - Transistors
- Cryogenic DC motor drive power stage was built and cryogenically tested to full power

Acknowledgements

- NASA JPL SBIR Program Contract NNC06CB35C

- Mohammad Mojarradi

Questions?